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Mineral-Oil Treatment of Sweet Corn for Earworm Control¹

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INTRODUCTION

Roasting-ear corn may be protected against injury by the corn earworm (*Heliothis armigera* (Hbn.)) by applying oil or oil containing insecticides to the tips of the ears. The value of oil when used for this purpose was first indicated in investigations made during the summer of 1936. That the oil could be made more effective by the addition of pyrethrins was first shown during February and March 1939, and in the summer of that year it was discovered that the pyrethrins might be replaced by dichloroethyl ether, a less expensive insecticide.

Sweet-corn varieties are especially attractive to the insect, and their protection usually is difficult, especially with varieties characterized by ears having loose or short husks. Such ears allow the worms to disperse rather soon after entry, to survive in large numbers, and to penetrate below the tip of the cob, where feeding causes particularly objectionable damage. If 100 eggs are laid on the silks of an ear, it does not suffice to prevent even 99 percent of the resulting earworms from reaching the kernels, since the 1 remaining worm would render

¹This circular supersedes the following processed publications of the United States Bureau of Entomology and Plant Quarantine: E-476, The Use of Oil for Earworm Control in Sweet Corn, issued in May 1939; E-497, The Use of Oil or Oil Containing Pyrethrins for Earworm Control in Sweet Corn, issued in February 1940; and E-525, The Use of Oil or Oil Containing Insecticides for Earworm Control in Sweet Corn, issued in January 1941.

an ear unsightly and lower its market value (fig. 1). Hence, if a method is to be successful, the control in each ear must be perfect.

It is possible that the insecticidal materials or apparatus recommended in this circular may become scarce on account of war conditions. In such case no satisfactory substitutes for these insecticides are known. Homemade apparatus for applying them, where available, probably could be improvised, however, from equipment and materials available around the farm.

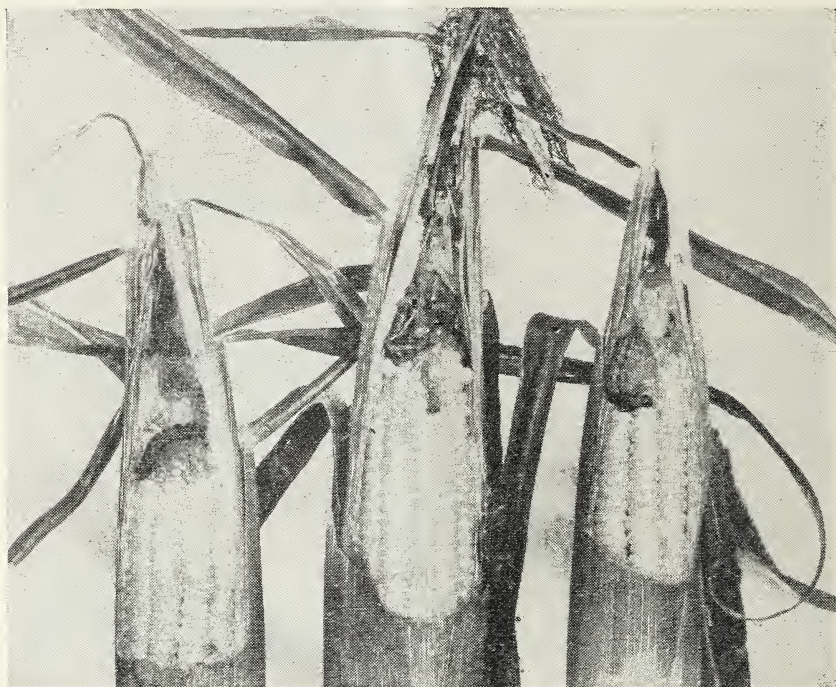


FIGURE 1.—Ears of sweet corn damaged at the tips by corn earworms.

SILKING HABITS OF CORN EARS

At first the corn ear is a closed package, but for the kernels to be fertilized the silks must be thrust out of the tip to receive pollen. The silks grow for a day or two and, if the weather is favorable, they become fertilized during the first few days of exposure. Each kernel must be pollinated through its single silk strand if perfect ears are to result. No method of controlling earworms must interfere with this process.

During the first day of exposure the silks stand upright or are spread apart singly to facilitate the reception of pollen by each strand (fig. 2, *A*). As the silk strands continue to lengthen, however, they fall to one side of the ear and gather in one hanging mass (fig. 2, *B*), and by the third or fourth day they begin to wilt (fig. 2, *C*). Thereafter the silk mass begins to dry and turn brown at the outer end, as shown in figure 3.

By the time the silk has begun to turn brown, all the kernels, except sometimes those at the tip of the cob, have been pollinated, and the application of control measures will not interfere with fertilization.

HABITS OF CORN EARWORMS

After the tip of an ear has opened to expose the silk it does not close again, and it is through this opening that most earworms gain access to the ear. Most of the earworms that reach the kernels of an ear hatch from eggs laid on the silks during the week following their exposure, particularly while they are fresh and unpollinated. The newly hatched worms, which emerge from the eggs about 3 days



FIGURE 2.—Appearance of silks of Golden Cross Bantam sweet corn during first few days of exposure: A, Silk strands on first day of exposure, spread apart to receive pollen; B, silks on second or third day after exposure, gathered in a mass, but pollination not necessarily complete; C, silks on third or fourth day after exposure, wilting, and pollination probably complete.

after they are laid, feed very little on the exterior silk but immediately crawl into the tip of the ear among the silk strands and begin to feed in this protected location. Sometimes, however, when the insect is abundant, eggs are laid on other parts of the plants, and often before the silks have become exposed. The resulting worms, which often feed on the tassels, are ready to enter the ears immediately after the silks become exposed, frequently as partly grown individuals. The application of insecticide to the exterior silks of ears that have become infested in this way may be ineffective because larvae may already have entered the ears.

Although to reach the kernels most of the earworms enter the ears by way of the silks, a few migrating individuals bore through the husk in a manner characteristic of the fall armyworm (*Leaphygma frugiperda* (A. and S.)) and the European corn borer (*Pyrausta nubilalis* (Hbn.)). Migrants sometimes move from the untreated to the treated ears in numbers somewhat in proportion to the density of the population. Under these conditions some of the treated ears may be attacked by migrating earworms, usually individuals of the fourth to sixth instars, which, probably being repelled from the treated tips, bore directly through the husks to the kernels. All the ears of a field should therefore be treated, irrespective of their marketability, so as to kill as large a percentage of the earworm population as possible.



FIGURE 3.—Appearance of ears of Golden Cross Bantam sweet corn as the silks dry: A, Silks on the fifth day after exposure, their tips beginning to dry; B, the drying a little further advanced; C, about the seventh or eighth day after exposure, the exterior silks dried about half way from their tips to the tip of the husk.

DETERMINING EXTENT OF INFESTATION IN CORN EARS

Before applying the mineral-oil treatment, the grower of sweet corn should be able to answer the following questions regarding the earworm infestation in his field: (1) Is the percentage of attacked ears sufficiently high to warrant the expenditure for control? and (2) at what time during the development of the ears can such control be applied most advantageously?

In the Southern States (approximately the area south of latitude 38°, or a line running through Maryland, northern Kentucky, and central Missouri) and on the Pacific coast the insect usually is sufficiently abundant to warrant the application of control measures to the ears of all sweet corn or other varieties used for roasting ears. In much of the eastern area north of this line, however, the abundance of earworms fluctuates from year to year and during different seasons of the year. In this northern area not all sweet corn is attacked, and it is well to determine the degree of infestation in a given field.

The presence or abundance of eggs on the silks has not proved to be a satisfactory index of the infestation that will follow, particularly for use by farmers. The eggs are small (somewhat larger than the period at the end of this sentence), and although they may be seen rather easily when laid on red or pink silks they are not nearly so easily seen when laid on green silks, such as those of the variety Golden Cross Bantam. Where only one or two eggs are deposited in the mass of exterior silks of the ear, they may be easily overlooked. Furthermore, eggs often are laid on the husks or on other parts of the plant where they may escape detection. Even if all the eggs could be found, their presence would not necessarily indicate the extent of infestation of the ears, inasmuch as some may become dislodged from the silks and many are devoured by predators, especially by the small bug *Orius insidiosus* (Say).

The best way for the grower to determine the extent of infestation is by looking for the worms in the interior silk of the ears. This can be done by selecting a number of ears as soon as the corn has silked and cutting the silks off cleanly with a sharp knife, together with the terminal 1 inch of the husk, and then splitting open the clipped tip of the husk to expose the interior silk. If larvae are present they may be seen lying among the silks, and their numbers may be determined. When only first instars, or larvae in the first stage of growth, are present, a magnifying glass may be needed to locate them quickly and without error.

These examinations enable the observer to determine how far within the ears the worms have penetrated. This depends largely on the prevailing stage of development of the ears and the size of the worms. Where the worms consist of small individuals (in the first or second stages of growth), most of them are usually found in the clipped terminal inch of the husk, and in this case the cut surface of the silk mass left with the cob will appear clean and without discoloration. Where larvae have penetrated farther than 1 inch into the ears, their presence may be detected by the brown spots on this cut surface. These spots consist of excrement and damaged silk, and the number of such spots indicates the number of worms that have penetrated more deeply than 1 inch into an ear. An examination of the remaining part of the interior silk above the tip of the cob will disclose the exact position in which these worms are feeding.

Such examination of ears so selected as to represent the entire cornfield, if made every 2 or 3 days during the first 10 days after silking has begun, will give dependable information on the percentage of ears attacked, the size of the larvae, the number per ear, and

the depth to which they have penetrated into the ears. From information thus gained, the grower may judge whether the infestation is sufficient to warrant expenditures for control, and at what time during the development of the ears control may be applied most effectively. Whether the ears should be treated for earworm control will depend on the price the grower expects to receive for them. If the expected price is a profitable one, control usually may be applied advantageously if 20 percent or more of the ears are infested.

USE OF OIL ALONE

When mineral oil alone is applied to the tips of the ears, it saturates the mass of silk that is enclosed by the husks above the tip of the cobs and serves as a barrier. The small larvae that are already in the silks at the time of treatment are killed, probably by being smothered, and small larvae that enter the silks after the oil has been applied also succumb or are repelled. Against larger larvae, especially those that migrate to the ears from the tassels in early corn, the oil alone is not very effective.

In tests of many vegetable and mineral oils, white mineral oils of from 150 to 250 seconds Saybolt viscosity at 100° F. were found to be the most satisfactory. These grades did not penetrate too deeply within the ear but established the desired barrier film among the interior silk strands between the tip of the husk and the tip of the cob, where the small larvae were killed. They are standardized products, pass the U. S. P. copper and acid tests, and are colorless, odorless, and tasteless. They are used medicinally, in small quantities are harmless to human beings, and do not adversely affect the flavor of green corn.

USE OF OIL CONTAINING PYRETHRINS

White oil to which pyrethrins have been added is an efficient contact insecticide that kills larvae of all sizes rather quickly. When oil and pyrethrins are used, the most desirable objective is not to establish a barrier in the interior silk at the tip of the ear but rather to disperse the material thoroughly throughout the interior silk so that it will come in contact with and kill all the contained larvae. On the other hand, the oil should not disperse so freely within the ear that much of it penetrates to parts where no larvae occur. When used as carriers of pyrethrins, white mineral oils of Saybolt viscosity from 100 to 150 seconds proved more effective than the heavier oils, as well as less expensive.

The effectiveness of oil containing pyrethrins is somewhat in proportion to its pyrethrin content. Considering the results of many field experiments and toxicity tests, and the cost of pyrethrum, it is believed that a content of 0.2 percent of pyrethrins in oil will give reasonably satisfactory earworm control under usual conditions.

Oils containing pyrethrins added by the manufacturer and oil to which pyrethrum extract was added by the user have proved to be equally effective. It is probable that the former will be the more convenient, if not the more economical of the two. For home preparation, however, if oleoresin of pyrethrum having a 20-percent pyrethrin con-

tent is available, add 38 cubic centimeters, or approximately $1\frac{1}{4}$ fluid ounces, of the extract to each gallon of oil to obtain a 0.2-percent pyrethrin content.

The use of pyrethrum extracts in which highly refined kerosene is used as the solvent cannot be recommended owing to the undesirable odor and taste of kerosene sometimes left on the ears.

USE OF OIL CONTAINING DICHLOROETHYL ETHER

Dichloroethyl ether is a colorless liquid that mixes readily with white oil when shaken or stirred thoroughly.

The results of many field experiments, toxicity tests, and the testing of treated ears by many persons showed that 2 percent of dichloroethyl ether in oil is the most satisfactory concentration for use in controlling earworms in sweet corn. Oil containing up to 3 percent of dichloroethyl ether caused injury to only an occasional ear, but stronger concentrations caused burning of the husk or rotting of the interior silk or cob tip. Although somewhat better protection from earworms was afforded the ears by the use of 3 percent of dichloroethyl ether in oil, the occurrence of residue on the kernels, as discussed later, showed that a 2-percent concentration was safer for general use, and a stronger concentration is not recommended. Dichloroethyl ether is available on the open market. To obtain a 2-percent mixture, add $2\frac{1}{2}$ fluid ounces of this per gallon of oil.

The effect of the oil-dichloroethyl ether mixture on earworms is different from that of either oil alone or oil containing pyrethrins. Although this mixture serves as a contact insecticide against some larvae, the volatilizing dichloroethyl ether acts as a fumigant against others. As it evaporates, the gas penetrates throughout the interior silk or even about the tip of the cob, often reaching and killing larvae that have not been wet by the mixture.

As with the oil-pyrethrum mixture, the oil-dichloroethyl ether mixture should penetrate thoroughly through the interior mass of the silk so that all the larvae may be wet by the mixture or reached by the evaporating gas. White mineral oil of Saybolt viscosity from 100 to 150 seconds is more effective than the heavier grades as a carrier of dichloroethyl ether.

WHEN OIL SHOULD BE APPLIED

If applied too soon after the silk has been exposed, mineral oil interferes with fertilization of the kernels. It should not be applied until the silks have become wilted, that is, not before about the third day after the first exposure (fig. 2, *C*). Since oil containing pyrethrins or dichloroethyl ether is effective against larvae in all stages of growth, it may be applied efficiently several days later than is satisfactory for oil alone. Any of the mixtures, however, usually should be applied before larvae reach the kernels at the tip of the cob, as determined by the method of sampling previously described. Applications of oil containing insecticides usually are most successful when made during the period between the time when the silks have wilted and the time when they are partly browned (fig. 3, *C*). Since the inclusion of insecticides in the oil permits successful treatment of ears later than was

satisfactory when oil alone was used, within a limit of 10 days after silks are first exposed, a longer time can be allowed to enable the ears to become completely pollinated before they are treated. Whether oil alone or oil containing an insecticide is used, the small kernels at the tip of the cob, which in some varieties often are not fertilized until much later than are the uniform-sized kernels of the remainder of the ear, occasionally fail to develop. It is not believed that this failure of the tip kernels to develop detracts greatly from the appearance of the ears or materially affects their desirability as roasting ears.

DESIRABLE TYPE OF SWEET-CORN EAR

The effectiveness of the mineral-oil treatment for earworm control has been found to vary when applied to different varieties of sweet corn, or when applied to the ears of one variety grown under different environmental conditions. This variation in effectiveness of control is correlated with the husk coverage of the ears. The grower might well consider this question when selecting a variety.

It has been found that when the mass of interior silk is pressed rather firmly by the surrounding husk, the larvae penetrate to the kernels more slowly and feed in the silk for longer periods than when the husks press less tightly on the interior silks or are so short that the larvae are able to crawl between the silk strands and reach the kernels soon after entering the ears. A high proportion of ears having reasonably long and tight husks can be protected against injury by earworms, but fewer can be protected in proportion as the husks of the ears are short or loose. This is because the oil dosage reaches most of the larvae within the enclosed silk mass and kills them but is less effective in reaching the larvae that have penetrated to the kernels.

The most desirable type of ear is one in which the husk presses rather tightly about the interior silk and the cob and extends 2 to 3 inches beyond the cob at the time of roasting-ear harvest. Ears of Golden Cross Bantam are examples of this type, when the plants are of vigorous growth. In addition to the possession of uniformly long, tight husks, other desirable characteristics in a sweet corn are the exposure of the silk of all the ears within a few days so that they can all be treated in one trip through the field, and the exposure of the silks of all the kernels of an ear at one time. An undesirable feature in some varieties is a secondary growth of the cob or silk several days after the first exposed silks have wilted. When this occurs, the application of oil at the proper time often interferes with fertilization and normal development of the kernels of the secondary growth.

EQUIPMENT FOR APPLYING OIL

Oil may be applied to corn ears as a spray, as an atomized mist, or by the use of an oiler, with results that are reasonably similar. Both spraying and atomization are wasteful, as they result in the loss of a large percentage of the oil through runoff. The oil and insecticides used are comparatively expensive, and if the treatment is to be economical the materials must be conserved. For this reason a simple equipment has been devised by means of which oil in measured quantities can be applied to corn ears without loss of material through

runoff. This equipment consists of force oilers of about 1 or 2 gills' capacity, shown in figure 4, connected to a 1-gallon can by a hose, as shown in figure 5. One gallon is sufficient oil to treat about 5,000 ears, or as much as can be applied by one man in half a day, and the can serves as a supply tank which feeds oil into the oiler by gravity. The complete equipment may be purchased from manufacturers, or it may be assembled inexpensively by growers.

The oilers, which serve in place of nozzles, are variously constructed by different manufacturers. Each is provided with an interior force pump controlled by a trigger. In the oiler shown at the extreme left in figure 3, pressure on the trigger forces down a plunger in a cylinder, and oil is forced out through the spout. Release of the trigger causes the plunger to rise through the action of a spring located beneath it, and more oil is drawn into the cylinder from the body of the oiler

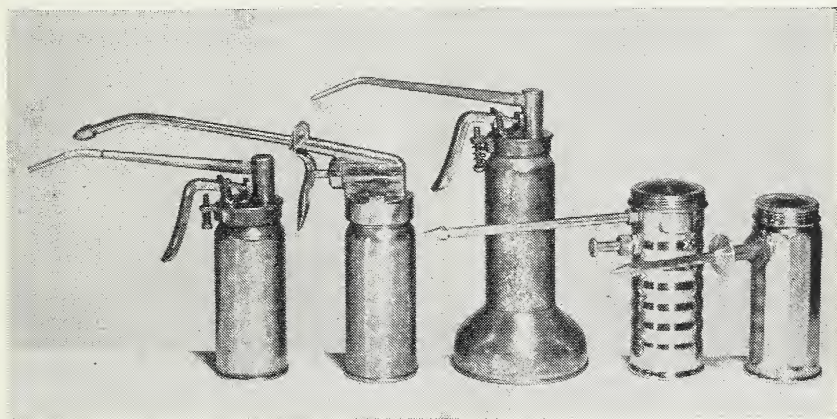


FIGURE 4.—Types of force, or pump, oilers that have been used to apply oil to sweet-corn ears for earworm control.

through a flutter valve, located in the base of the cylinder, that opens only inward. Oil is prevented from returning from the spout by a ball-and-socket valve which opens only outward. An adjustable setscrew regulates the length of the stroke of the trigger, and this in turn controls precisely the quantity of oil ejected by the oiler at each squeeze of the trigger. Marks can be placed on this setscrew indicating the proper positions to give dosages ranging from 0.5 to 1 cubic centimeter per trigger squeeze. The oilers shown in figure 3 fit the hand somewhat like a pistol grip and are not tiring to use for hours at a time. One hand remains free to adjust the corn plants as the ears are oiled.

If airtight oilers such as the two on the right and the second from the left in figure 4 are used in assembly with a storage tank, it is necessary to remove the cover and fill the oiler with oil before it can be used, since otherwise it will be air-bound.

A rectangular oilcan, such as those in which lubricating oil is sold, may be used as part of the equipment and serves as a supply tank. To allow connection of the supply can to the oiler, a section of $\frac{3}{8}$ -inch pipe about 2 inches long is soldered into the base of the oiler, and a similar piece of pipe is attached to the base of the supply can. The

oiler and supply can are then connected by means of a piece of hose about 3 feet long, preferably of oil-resistant construction. A small hole is punched in the side of the supply can just under the top rim to serve as a vent. A piece of fine wire screening may be soldered about this vent if desired. Trash cannot easily enter a vent so placed. The proper location and screening of the vent are important because dry pollen sacs from the corn tassels, which are easily shaken loose, may interfere with operation of the oiler if they enter the oil supply.

To aid in applying the oil to each ear as uniformly as possible, a metal disk or washer about three-fourths of an inch in diameter may be mounted on the spout of the oiler about half an inch from the tip, as shown in figure 5. This gages the depth to which the tip of the

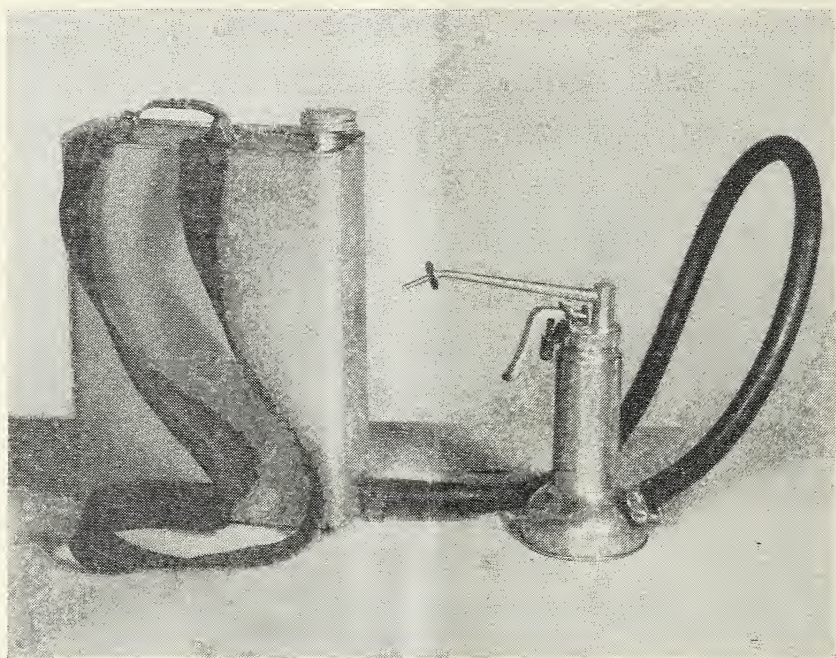


FIGURE 5.—Home-assembled knapsack equipment for applying oil or oil containing insecticides to corn ears for earworm control.

spout should be inserted into the ear tip before the oil is injected. The use of an oiler so equipped results in less loss of oil through runoff than occurs when it is applied to the exterior silk and in placing the oil where it will be most effective.

The supply can may be suspended over one shoulder or in the middle of the back by means of one or two straps, pieces of rope, or strips of cloth or burlap attached to its handle, thus freeing both hands for use in treating the ears. A convenient method of carrying the supply can, especially when oiling ears that are from knee to waist high, is a belt sling, shown in figure 6. An adjustable strap slung from the belt allows the supply can to be carried at the level of the belt, or part way between the belt and the knee as shown. This method of carrying the supply can allows the fullest use of the arms and the upper part of the

body. When in use the oiler may be filled by simply lowering it whenever necessary until oil flows into it from the supply tank. Experience will enable one to judge by the weight of the oiler approximately how much oil it contains and when it is necessary to lower it for refilling.

Growers having considerable acreage usually have provided themselves with several oilers assembled as described and have sent the workers into the fields in groups under a leader to apply oil to the



FIGURE 6.—Belt carriage of oiling equipment especially adapted for treating ears that grow from knee to waist high.

ears. If the acreage is large, it may be advisable to plant portions of it at intervals a few days apart so the ears will come into the proper stage of growth for treatment over a period sufficiently long to enable the workers to apply the control to ears in a uniform stage of growth.

Some growers who have small fields have found that oilers can be used satisfactorily without connection to supply cans. A container of oil is placed at each end of the field, and the oiler is refilled after the treatment of the ears in each row is completed.

QUANTITY OF OIL NEEDED PER EAR

The oil or oil containing an insecticide, when applied to the tips of ears, seeps quickly into the interior silk. The introduction of too much oil into an ear is likely to cause rotting, especially if it penetrates too deeply about the kernels. On the other hand, when too little is used, it fails to penetrate through the interior silk sufficiently to reach all the larvae that may be feeding there. For ears of the type of Golden Cross Bantam, dependable results were obtained when from $\frac{3}{4}$ to 1 cubic centimeter (about $\frac{1}{4}$ teaspoonful) of oil was used per ear. This quantity is sufficient if it is applied by means of an oiler, such as that shown in figure 4, so that little is lost through runoff. To be sure that a suitable dosage is being applied, the oiler should be checked frequently by each worker and adjusted so that the precise dosage mentioned is ejected per trigger squeeze.

When oil is applied by atomization or spraying there is no means of determining how much seeps into a given ear and how much is lost through runoff. By those methods of application, the ears receive variable dosages, the control is less uniform, and occasional injury is done to the ears by the insecticides.

COST OF APPLYING OIL CONTAINING INSECTICIDES

Studies of the time consumed in oiling showed that a rather rapid worker could oil ears at a rate of 1,500 per hour, or 12,000 per 8-hour day. Assuming an average of 9,000 ears per acre and the application of three-fourths of a cubic centimeter of oil per ear, an acre of corn could be oiled by one man in 6 hours, using about 2 gallons of oil.

In using oil of 200 to 210 seconds viscosity alone, at a cost of 80 cents per gallon and labor at \$2.50 per 8-hour day, the total cost of treating 1 acre of sweet corn would be \$1.60 for oil and \$1.88 for labor, or a total of \$3.48. With 9,000 ears per acre, or 750 dozen, the cost of oiling would be about 4 cents per hundred ears, or half a cent per dozen, under most favorable conditions.

At a price of about \$7 per pound for 20-percent pyrethrum extract, or \$6 per gallon for 2.5-percent pyrethrum extract, 0.2 percent of pyrethrins could be added to oil by the grower for a cost of less than 80 cents per gallon. If white oil of from 100 to 150 seconds viscosity is used, the total cost of the mixture should not exceed \$1.60 per gallon. At this price the cost of treatment per acre would be \$3.20 for oil containing pyrethrins and \$1.88 for labor, or a total cost of \$5.08 under most favorable conditions. With 9,000 ears per acre the cost of such treatment with oil-pyrethrum would be about $5\frac{1}{2}$ cents per 100 ears, or about two-thirds of a cent per dozen.

Dichloroethyl ether is inexpensive, and the addition of 2 percent of this chemical to oil increases the cost of the mixture by not more than 5 cents per gallon, but as it is used with oil of from 100 to 150 Saybolt seconds viscosity, the total cost of treatment per acre would be approximately that mentioned for oil alone.

The costs mentioned are necessarily only approximate, since current prices, cost of shipment to various locations, and the cost of labor will vary. Moderate increases in the cost of the materials, however, will not materially affect the approximate costs of the different treatments per 100 or per dozen ears.

The cost of oiling depends largely on the variety of corn to be oiled. When grown under favorable conditions, approximately 80 percent of the ears of the hybrid variety Golden Cross Bantam can be oiled in one trip through a field because of the uniformity in time of silking. With open-pollinated varieties, having less uniformity in time of silking, more than one trip through a field may be necessary in order to treat the ears in the proper stage of development. Under such conditions the cost of applying oil becomes correspondingly greater.

MARKING OF OILED EARS

Where silk exposure is not uniform and it is necessary to make more than one trip through a field to oil a suitably large percentage of ears, ability to recognize the ears first treated is necessary so that a second dosage of oil will not be applied to them. Not only is more than one treatment wasteful of the insecticide, but it should be particularly avoided if dichloroethyl ether is used because of the danger of leaving detectable residues if too much of the mixture is injected into the ears, or if a dosage is applied too near the time of harvest. A number of methods of marking the treated ears that proved unsuccessful or impractical have been suggested and tried. One of the most promising methods tried thus far is to punch a hole in the leaf that springs from the same node as the ear and is wrapped about its shank. A hole about half an inch in diameter is conspicuous when punched in this leaf about 4 inches from the ear. The applicator can be carried in one hand and a suitable punch in the other, and a hole can be punched quickly in the leaf as the ear is treated.

In southern California some growers have marked treated ears with lumber crayons or paint. In the latter method a $\frac{1}{2}$ -pound paint can containing a pad and thin paint is belted to the waist at the left hip. One dip of the thumb will mark half a dozen ears. Different colors can be used for different oilings. The thumb of the free hand is inked on the pad, and then the ear is grasped with this hand while the oil is injected with the other hand. Thus the ear is marked and treated at the same time with the least possible expenditure of time for marking.

EFFECT OF OILING ON FLAVOR OF KERNELS

White oil, being colorless, odorless, and tasteless, leaves no detectable residue on the kernels of treated ears.

Although the addition of 0.2 percent pyrethrins colors the oil slightly brown, this mixture does not change the appearance of the silks or kernels of treated ears. A slight musty odor of pyrethrum may be detected occasionally in the interior silks, but no alteration of flavor of the kernels has been detected when oil-pyrethrum was used as here recommended.

If a residue of dichloroethyl ether remains on the kernels it can be detected by odor and by taste, but when properly used under usual summer conditions the insecticide usually evaporates completely from the ears between the time of treatment and the time of harvest. Certain precautions should be observed in the use of this material, however, and growers should familiarize themselves with the hazards involved before undertaking treatment of a large acreage with oil-

dichloroethyl ether. The rate of evaporation of dichloroethyl ether depends on temperature, and applications should be timed so that at least 10 days intervene between treatment and harvest of roasting ears, except during very warm weather. In localities where, and during periods of the year when, the average mean temperature of this 10-day period falls below 65° F., or the night temperature often falls below 60° F., oil-dichloroethyl ether should be used with caution, and treated ears should be examined by smelling the silks and tip kernels before marketing them, in order to reject those having a strong odor of dichloroethyl ether.

In general it has been found that oil-dichloroethyl ether may be used on slowly developing varieties such as Maule's Lead-all with less danger of residue remaining on ears at roasting-ear harvest than on ears of more rapidly developing varieties such as Golden Cross Bantam. In the cooler periods of the year oil-pyrethrum will usually prove to be a safer treatment than oil-dichloroethyl ether. When oil containing an insecticide is applied at the dosage and in the manner described herein, residues will probably be detected only rarely and then usually will affect only the tip kernels of treated ears.

EFFECTIVENESS OF OILING

When oil alone is used, its effectiveness is correlated with the character of the corn husks. In general the degree of protection against earworm injury is comparatively low where husks are short or loose and increases in proportion as they are longer and tighter. In ears having tight husks the earworms must penetrate downward through the interior silk largely by eating their way, whereas in ears having loose husks they may readily crawl downward between the silk strands. In tight-husked ears there is a better opportunity for the oil to come in contact with them and kill them. Ears having long, relatively tight husks (extending at least from 2 to 3 inches beyond the cob at the time of roasting-ear harvest) provide a suitable place for establishing and maintaining an oil barrier, and the oil tends to saturate and remain as a film about the strands of the interior silk, whereas ears having short husks do not provide a place for the oil barrier to become established, and if the husks are loose the oil may spread downward through the silk and about the kernels.

With the use of insecticides in the oil, extreme husk development becomes a less important factor than when oil alone is used. This is because the oil containing pyrethrins kills the worms by contact, and oil containing dichloroethyl ether kills them either by contact or by fumigation, rather than by smothering them in a barrier of oil-saturated silk located near the tip of the husks. Therefore when oil containing pyrethrins or dichloroethyl ether is used, it should penetrate throughout the interior silk so as to reach all the larvae. This is especially necessary if the ears are oiled after the silks have become partly browned, since by this time the worms will have gone deeper into the silks than where they occur immediately after pollination, the most satisfactory time for applying oil alone.

The use of oil containing an insecticide has been most successful in varieties in which the husk is uniformly but not excessively developed and of an average length of between 2 and 3 inches beyond the tips of the cobs at the roasting-ear stage of growth. In varieties such as

Kancross, in which the husks of the ears are extremely long, the mass of interior silk is so great that after larvae begin to tunnel within the silk a dosage of more than 1 cubic centimeter of oil containing an insecticide may be needed per ear to reach and kill a large percentage of them. In general the use of oil containing an insecticide gives as good earworm control in ears of sweet-corn varieties having moderately long, tight husks as has been obtained with oil alone in varieties having longer and tighter husks. Although ears with long husks are not necessary for the successful use of oil containing an insecticide, uniform development of moderately long husks is very important; for if some of the ears have very short or very loose husks the worms will probably reach the kernels of those ears before pollination is completed and before the oil containing an insecticide can safely be applied.

To sum up: Oil alone, or oil-pyrethrum, or oil-dichloroethyl ether may be applied to the ears. Each of these insecticides remains effective under all weather conditions, and control is obtained by a single application per ear.

Although oil alone is not so effective against large earworms as against small ones, the oil-pyrethrum or oil-dichloroethyl ether is effective against larvae of any size. Because some larvae migrate from one ear to another, however, and when repelled from entering the tips of ears through the treated silks sometimes bore directly through the husks to reach the kernels, it is important to kill as large a percentage of the earworms present in a cornfield as is possible. For this reason the number of migrating larvae should be kept low by oiling all the ears in a field, including the unmarketable ones.

The results of many field experiments in New Jersey and Florida during several years, and of practical use of the treatments by growers of sweet corn, indicate that under usual conditions, when the plants are of vigorous growth and have not been adversely affected by drought and when all the ears are infested, the average expectancy of earworm control in ears of Golden Cross, Bantam or similar varieties is about 60 percent if oil alone is used, and from 75 to 85 percent if oil containing 0.2 percent pyrethrins or 2 percent dichloroethyl ether is used.

In some sections of the country corn ears are attacked by caterpillars having habits somewhat similar to those of the corn earworm. The most common of these are the fall armyworm, occurring principally in the South but occasionally invading the North during the fall, and the European corn borer, occurring in the Northeast. The larvae of these insects often enter corn ears by way of the silk, but they also feed among the husk leaves or in the shank, and many of them habitually reach the kernels by boring directly through the husks. The oil containing insecticides is as effective against larvae of both these species as against earworms when they enter the ears through the silks, but it does not reach them, and therefore is not effective, when they burrow through the husks or other parts of the ears. Within their range the larvae of these species often occur coincidentally with earworms, and in the fall of the year, in the Northeast, all three species may be present in ears of late corn. When evaluating the effectiveness of oiling, one should be certain that he is dealing with the corn earworm only and that injury caused by other species is not attributed to this insect.

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